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Report 2389

EVALUATION OF THE PERFORMANCE OF FILTER SEPARATORS WITH GASOHOL

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This report covers decontamination tests conducted on military standard filter/coalescer elements using unleaded gasoline and unleaded Gasohol (10 percent ethanol in gasoline). The use of Gasohol demonstrated improved solids removal ability over that of gasoline. Water removal efficiency could not be measured adequately as the injection of water caused separation of the Gasohol into two phases. Filter coalescer elements used with Gasohol act as contacting columns in the presence of water; their use is not recommended when water is present.

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PREFACE

Authority for conducting the research described in this report is contained in the Science and Technology Objectives Guide, 82-3:2, -3:11.

Tests were conducted during November and December 1981 in the POL Test Facility, MERADCOM, Fort Belvoir, Virginia.

The work was conducted under the supervision of M. E. LePera, Chief, Fuels and Lubricants Division.

The following MERADCOM personnel participated in the test program:

William R. Williams, Chemical Engineer.
William J. Johnston, Engineering Technician.

CONTENTS

TABLES

EVALUATION OF THE PERFORMANCE OF FILTER SEPARATORS WITH GASOHOL

I. INTRODUCTION

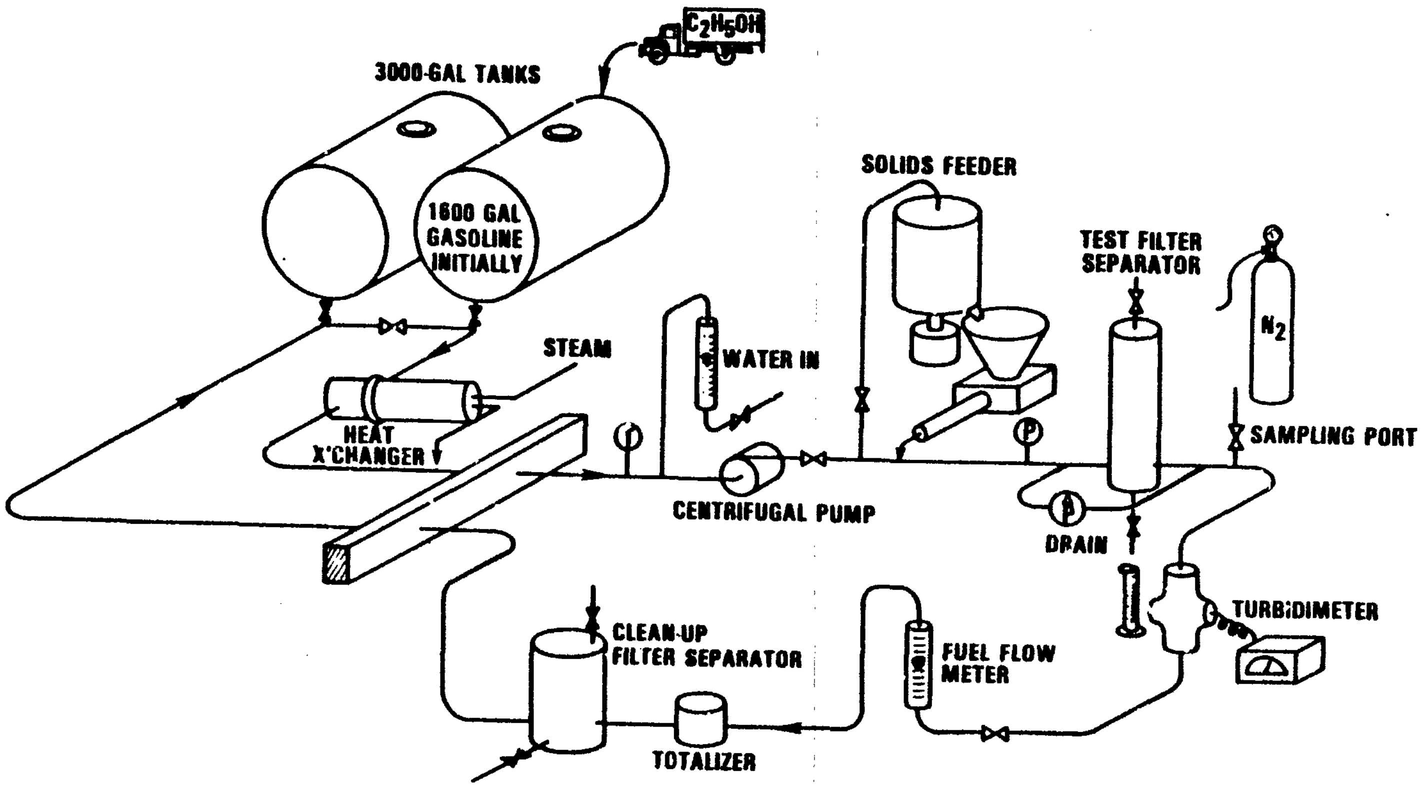
1. Subject. This report covers performance tests on a Military Standard Filter Separator using regular unleaded gasoline and regular unleaded Gasohol.

2. Background. The Army Gasohol program was initiated in late 1979 to determine the effects of using Gasohol in place of gasoline on the performance of Army vehicles and ground support equipment. Later, the program was extended to include fuels-handling equipment, collapsible tanks, and filter separators.

Filter separators are primarily designed to remove suspended water and solids from aircraft fuels (turbine fuel and aviation gasoline). They are mandatory for use in the refueling of aircraft. They are also recommended for use with ground fuels—diesel fuel and motor gasoline. Their effectiveness with gasoline has been determined to a limited degree, but no data exist with Gasohol.

II. INVESTIGATION

3. Test Facility. The test facility consists of a nominal 20-gal/min pumping loop capable of operation on a recirculating basis or on a single-pass basis. A schematic of the pumping loop is shown in the figure on the following page. In general, the test facility is similar to that described in Military Specification MIL-F-8901, "Filter Separator, Liquid Fuel and Filter Coalescer Elements, Fluid Pressure: Inspection Requirements and Test Procedure For." Two 3000-gal cylindrical tanks serve as feed and receiving tanks. A centrifugal pump circulates fuel from one tank to the other or within a single tank. A 20-gal/min Military Standard Filter Separator contains a single DOD standard coalescer element as the test item. Water is injected into the fuel stream just ahead of the centrifugal pump creating a water-in-fuel emulsion which represents the influent to the filter separator. Solids are injected using a solids feeder coupled to a positive displacement (Moyno) pump. Appropriate gauges measure fuel temperature and pressure drop across the filter separator. Water level in the effluent is measured by a flow-type turbidimeter (Keene Model 861 B) calibrated to read suspended water over the range of 0 to 5000 p/m. A sampling port just downstream of the filter separator is equipped for the collection of bottle samples and for the attachment of Millipore monitoring equipment for determination of solids level and fiber count. A clean-up filter separator is used to remove any residual water or solids that may have passed through the test filter separator. A heat exchanger controls fuel temperature to within plus or minus 5 degrees. The high volatility and flammability of the gasoline and Gasohol necessitated special safety precautions including the use of a nitrogen purge system to evacuate air from the filter separator prior to pressurization.



Testing loop.

4. Filter/Coalescer Elements. The filter/coalescer elements used in the tests conform to the requirements of Military Specifications MIL-F-8901 and MIL-F-52308 and are standard DOD items listed under NSN 4330-00-983-0998. The test elements were from Lot No. 168-79, manufactured by Banner Filters.

5. Test Fuels. Approximately 1600 gal of regular unleaded gasoline was procured from the Fort Belvoir Motor Pool. This fuel met the requirements set forth in Federal Specification VV-G 1690. Prior to use, the gasoline was circulated through a filter separator for several hours to remove any residual water or solids. After the tests with gasoline were completed, the fuel was made into Gasohol by the addition of 10 percent ethanol. The ethanol has been rendered completely denatured with gasoline and had a minimum purity of 199+ proof. The ethanol met the requirements set forth in the Code of Federal Regulations Booklet 27 CFR 212. Mixing was accomplished by use of the circulating pump for approximately 2 h. The mixed product was analyzed for ethanol level and found to be within the standards set forth in Military Specification MIL-G-53006.

6. Test Contaminants. Water injected into the fuel during the test was supplied by the Fort Belvoir water utility system. Prior to use, the water was filtered to a residual solids level of less than 1 mg/l. Solid contaminant was finely divided red iron oxide (Fe_2O_3) obtained from Fisher Scientific Company (Cat. No. I-116).

7. Test Procedures. The tests described in the following paragraphs were based upon those described in Military Specification MIL-F-8901. Some modifications were necessary to accommodate the unique properties of the fuel and the fact that only one test element was used instead of two. All tests were performed first with gasoline and then with Gasohol. Most tests were performed with the fuel being recirculated continuously within a single tank as the fuel was not changed as a result of the tests and the clean-up filter separator ensured that any residual contaminants were removed. For those tests involving water injection into Gasohol, however, the fuel was allowed to make only a single pass—from one tank to the other. It was thought that there might be some leaching out of ethanol as a result of the water injection so that make-up ethanol might have to be added to the receiving tank at the end of the test.

a. Differential Pressure and Media Migration Test. This test measured pressure drop under normal operating conditions (no addition of contaminants) and the number of fibers in the effluent. The fiber count was an indication that the fiberglass of the coalescer element was being degraded by the action of the fuel. Fiber count was measured by a Millipore 0.8. μ membrane with an imprinted grid.

b. Red Iron Oxide, Dry. This test measured the ability of the filter element to filter out solid particles. The same filter element used in the Differential Pressure and Media Migration Test was used in this test. Red iron oxide was injected at a fixed rate and at a fixed fuel flow rate for 70 min or until a pressure drop of 75 $lb/in.^2g$ was obtained. Measurements were made of pressure drop, temperature, and solids level in the effluent. Solids level was measured by using a Millipore 0.8 μ Matched Weight Monitor.

c. Water Removal. The water removal test was a 1-h test with new filter elements installed. During the first 30 min, water was injected at the rate of 0.5 percent; the second 30 min, water was injected at the rate of 5.0 percent. Pressure drop and temperature were recorded. Water level in the effluent was measured with a turbidimeter and by volumetric analysis of bottle samples. In addition, the water separated by the filter-separator was collected and its volume measured and compared with the total volume of water injected to calculate the percent separated.

d. Post Environmental. This was a modified water removal test using new filter elements that had been presoaked in the test fuel for 72 h prior to testing. After soaking, the filter elements were examined for deterioration, elastomeric swelling, etc. The test required water injection at the rate of 0.5 percent.

III. DISCUSSION

8. Discussion of Results. Test data are shown in Tables 1 through 4, comparing gasoline and Gasohol results. Significance of the test results, test by test, is as follows:

a. Differential Pressure and Media Migration. Little significant differences in the differential pressures were noted. The higher fiber count for Gasohol may indicate that the alcohol was causing some filter element deterioration, possibly due to a solvent action on the internal sealants.

b. Red Iron Oxide, Dry. While sample analyses were scattered, examination of the filter elements and the pressure drop data clearly indicates that Gasohol tends to encourage solids removal. The Gasohol filter element showed red iron oxide caked on its inside periphery; the gasoline element had red iron oxide bleeding throughout its diameter. Likewise, the high-pressure drop for Gasohol was caused by the large quantity of solids retained by the element. It is thought that the alcohol in the Gasohol counteracted the surfactant action of the detergent additives in the gasoline. The surfactant tended to surround each microscopic solid particle preventing agglomeration and retention on the fiber bed of the filter.

Table 1. Test Series I

Test Conditions			Test Fuel: Gasoline, Automotive, Unleaded, Meeting VV-G-1690 Test Date: 16 Nov 81			Test Fuel: Gasohol, Automotive, Unleaded, Meeting MIL-G-53006 Test Date: 23 Nov 81		
Time (min)	Flow (gal/min)	Rated Flow (%)	Fuel Temp (°F)	Differential Pressure ($lb/in.^2 g$)	Effluent Fibers (No./l)	Fuel Temp (°F)	Differential Pressure ($lb/in.^2 g$)	Effluent Fibers (No./l)
10	20	100	82	4.7	1	80	4.4	4
20	20	100	82	4.7	1	82	4.5	6
30	20	100	82	4.8	1	83	4.9	6
40	20	100	82	4.8	1	83	5.3	2
50	20	100	82	4.8	0	83	5.5	No data
60	20	100	82	4.8	4	83	5.9	4

NOTES:
Test: Differential Pressure and Media Migration, based on MIL-F-8901, para 4.4.3.6.
Filter Element: Banner Lot 168-79.

Table 2. Test Series II

Test Conditions				Test Fuel: Gasoline, Automotive Unleaded, Meeting VV-G-1690 Test Date: 16 Nov 81			Test Fuel: Gasohol, Automotive Unleaded, Meeting MIL-G-53006 Test Date: 23 Nov 81		
Time (min)	Flow (gal/min)	Rated Flow (%)	Injected Fe_2O_3 (g/gal)	Fuel Temp (°F)	Differential Pressure ($lb/in.^2 g$)	Effluent Solids (mg/l)	Fuel Temp (°F)	Differential Pressure ($lb/in.^2 g$)	Effluent Solids (mg/l)
0	20	100	0	76	4.7	*	82	6.6	*
10	20	100	0.143	78	4.7	2.08	82	6.9	*
20	20	100	0.143	80	4.7	0.32	83	8.6	0.25
30	20	100	0.143	82	4.9	2.83	83	9.3	0.29
40	20	100	0.143	82	5.1	3.59	84	10.6	*
50	20	100	0.143	83	5.4	*	84	11.5	1.13
60	20	100	0.143	84	5.7	1.28	84	13.5	*
70	20	100	0.143	84	5.8	*	84	15.2	2.16

NOTES:
* No Data.
Test: Red Iron Oxide, Dry, based on MIL-F-8901; para 4.3.3.7.
Filter Element: Banner Lot 168-79.

Table 3. Test Series III

Test Conditions				Test Fuel: Gasoline, Automotive, Unleaded, Meeting VV-G-1690 Test Date: 18 Nov 81			Test Fuel: Gasohol, Automotive, Unleaded, Meeting MIL-G-53006 Test Date: 24 Nov 81			
Time (min)	Flow (gal/min)	Rated Flow (%)	Injected H_2O (%)	Fuel Temp (°F)	Differential Pressure (lb/in.^{2}g)	Effluent H_2O via Turbidimeter (p/m)	Fuel Temp (°F)	Differential Pressure (lb/in.^{2}g)	Effluent H_2O via Turbidimeter (p/m)	Effluent H_2O via Volumetric Analysis (p/m)
0	20	100	0	87	4.7	0	81	4.3	0	0
10	20	100	0.5	87	7.4	10	82	4.4	2100	6,450
20	20	100	0.5	87	7.6	18	82	4.4	1600	4,330
30	20	100	0.5	86	7.9	23	82	4.4	2700	8,771
40	20	100	5.0	85	8.6	83	82	5.4	5000+*	68,700
50	20	100	5.0	84	8.8	93	–	–	–	–
60	20	100	5.0	84	9.1	168	–	–	–	–

Gasoline: Total water injected: 124.9 liters
Water collected from Filter Separator: 82.75 liters
Separator Efficiency: 66.25%

Gasohol: Total water injected: 49.2 liters
Aqueous phase collected from Filter Separator: 30.3 liters
Water: 1.5 liters
Ethanol: 0.9 liter
Separator Efficiency: 3.05%
*Off Scale

NOTES:
Test: Water Removal, based on MIL-F-8901, Para 4.4.3.8.
Filter Element: Banner Lot 168-79.

Table 4. Test Series IV.

Test Conditions				Test Fuel: Gasoline, Automotive, Unleaded, Meeting VV-G-1690 Test Date: 20 Nov 81			Test Fuel: Gasohol, Automotive, Unleaded, Meeting MIL-G-53006 Test Date: 3 Dec 81			
Time (min)	Flow (gal/min)	Rated Flow (%)	Injected H_2O (%)	Fuel Temp (°F)	Differential Pressure (lb/in.^{2}g)	Effluent H_2O via Turbidimeter (p/m)	Fuel Temp (°F)	Differential Pressure (lb/in.^{2}g)	Effluent H_2O via Turbidimeter (p/m)	Effluent H_2O via Volumetric Analysis (p/m)
10	20	100	0	88	3.9	0	85	4.8	0	0
20	20	100	0.5	88	5.6	1	85	5.2	2700	4000
30	20	100	0.5	89	7.1	5	86	5.3	2700	4000
40	20	100	0.5	89	7.4	10	86	5.4	2900	4000
50	20	100	0.5	89	7.4	12	86	5.4	2900	4000
60	20	100	0.5	89	7.4	14	86	5.5	3200	4000
70	20	100	0.5	89	7.4	15	86	5.5	3000	4000

Gasoline:
Total water injected: 22.7 liters
Water collected from Filter Separator: 16.4 liters
Separator Efficiency: 77.25%

Gasohol:
Total water injected: 22.7 liters
Aqueous phase collected from Filter Separator: 18.9 liters
Water: 1.9 liters
Ethanol: 1.9 liters
Separation Efficiency: 0.70%

NOTES:
Test: Post Environmental Water Removal Test, based on MIL-F-8901, para 4.4.3.17.
Filter Element: Banner Lot 168-79.

c. Water Removal. The differences between gasoline and Gasohol in this test are dramatic. The gasoline test demonstrated that the filter separator was coalescing the suspended water droplets. The effluent water level indicated that gasoline was less effective than turbine fuel but more effective than diesel fuel in its ability to effect water coalescence. There is no evidence that any coalescence took place with Gasohol. Instead, the filter separator appeared to act as a contacting column. The injected water caused separation of the Gasohol into phases: a fuel rich phase and an ethanol-rich phase. The lower phase—the ethanol-rich phase—was continuously drained off the bottom of the filter separator. This phase was found to be mostly gasoline with some ethanol and water. The upper or fuel-rich phase passed into the effluent after it had been stripped of much of its ethanol. It also contained large quantities of suspended water. The lower pressure drop experienced with the Gasohol was another indication of the lack of any real coalescence. Much of the water passed through the effluent and got back to the receiving tank where it caused separation of about 1700 gal of Gasohol; only after several decantations was some of the fuel saved.

d. Post-Environmental Water Removal. This test turned out to be a repetition of the Water Removal Test. The governing factor was, once again, the huge quantity of water in the Gasohol effluent; the environmental factor could not be evaluated.

IV. CONCLUSIONS

9. Conclusions. Based upon the results obtained, it is concluded that:

a. Gasohol may have some deleterious effects on the integrity of filter coalescer elements.

b. Filter separators show improved solids removal ability when tested with Gasohol over those tested with gasoline.

c. No effective coalescence of water from Gasohol can be accomplished.

d. Filter separators are not recommended for use with Gasohol except when the fuel is dry and contains a high-solids level.

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